Implementing Solutions for Muskrat Lake

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Abstract

Muskrat Lake has recently been suffering from nutrient overloading due to unknown causes. The purpose of this investigation is to determine where excess nutrients are concentrated in the Muskrat Lake watershed, to monitor their levels over a six-week period, and to test the BioCord Reactor as a novel solution. The reactor is commonly used in man-made wastewater remediation systems to increase the level of biological treatment, and decrease concentrations of nitrogen and phosphorus. Collection bottles were rinsed three times at each collection site before samples were taken and shipped to the Canadian Nuclear Laboratories and the Ministry of Environment for analysis, or brought back to the lab. Lab equipment was purchased from HACH Industries, and the HACH TNT Kit 843 procedure was slightly modified to scan for an ultra-low level of phosphorus. Overall, the results suggest that agricultural runoff, the mixed wood forests, and the municipal wastewater treatment plant do not have significant impacts on the watershed, but more analysis is necessary before any definitive conclusions can be drawn. Furthermore, the BioCord Reactor was shown to be ineffective at the test site due to low rainfall, water depth, and water speed. More sites need to be analyzed for a longer period of time in order to determine if this technology is feasible as a short-term remediation tool for eutrophication.

Key Words

Eutrophication, Muskrat Lake watershed, biofilm, agricultural runoff, wastewater treatment

Introduction

Muskrat Lake is located directly north of Cobden, Ontario — a town with a population of approximately 1000 people. The residents are primarily farmers who grow a variety of corn, wheat, and soybeans (1). A study done by Algonquin College and the Muskrat Watershed Council has confirmed that the area suffers from an excess of essential nutrients like nitrogen and phosphorus (1). Other small lakes in Ontario, such as the ones in the Experimental Lakes Area near the Kenora District of Ontario, have recently been suffering from the same problem (2). The findings from this research can be extrapolated to help other watersheds facing similar issues, and

highlight the need for more of such studies.

The Muskrat Lake watershed consists of three lakes that all eventually drain into the Ottawa River. Lake Doré is the origin of Snake River (SNR), which drains into Muskrat River (MKR) and Muskrat Lake. Mink Lake is the source of Mink Creek (MC), and connects to the Snake River. There are multiple small water passageways, such as the Upper Harris Drain (HC), which originate at the Northern Tributary (NT) and meander through farmland to enter Snake River. This report numbers sites consecutively, with lower numbers representing further upstream. There are a total of 24 sampling sites throughout the watershed that are analyzed year round, but this report will focus primarily on 10 sites in order to analyze the concentrations of nutrients before and after a possible location of nutrient overloading.

Nutrient overloading from both point and non-point sources can lead to eutrophication, which is the increased growth of microscopic plant and algae. The primary source of point pollution is at MKR-02, which is where the municipal sewage treatment plant is located (Figure 1 and Table 1). Partially treated discharge from the plant is released into the wetland, where the water is remediated further naturally. There are also many non-point sources of pollution, such as agricultural run-off and storm water discharge. This study will analyze both point and non-point causes in order to determine the principle cause of the high nutrient levels.

Eutrophication leads to many disastrous consequences, such as lake stratification. This naturally occurring phenomenon separates the lake into three distinct layers: the epilimnion, the thermocline, and the hypolimnion. The epilimnion has the highest oxygen concentration because photosynthesis from the excess plant growth produces non-compound oxygen, which winds mix and thus aerate the water naturally. Six to eight metres below the surface is the thermocline, where dead plants sink and decompose. Aerobic bacteria consume the material, resulting in an oxygen sag that prevents the upper and lower layers of the lake from mixing. Due to this stratification and lack of blending, the hypolimnion has low oxygen levels that lead to fish deaths (3).

The principle objectives of this investigation is to determine the rationale behind elevated nutrient levels throughout the watershed, and to determine the effectiveness of the BioCord reactor. The data obtained from water samples at different sites will reveal where nu-

Figure 1: Map of the Muskrat Lake Watershed.

Refer to Table 1 for the location of each point located on the map.

trient levels are highest, and where remediation efforts should be concentrated. A case study done on a municipal sewage treatment plant by the inventor of the reactor demonstrated that the system is capable of reducing nitrogen levels from 22 mg/L to 3.9 mg/L (4).

This report hypothesizes that agriculture is the main source of eutrophication due to nutrient overloading from fertilizer runoff, and that water samples downstream of farmland will have higher nutrient levels than those recorded upstream. The cost and level of technicality required to implement certain best management practices on farmland discourages farmers from executing more environmentally friendly solutions (5). Many are also uninformed of the negative impacts that runoff and erosion have on waterways (1). In order to resolve these issues, more information needs to be shared with farmers and the public to educate them on how to mitigate their impact on the environment.

Experimental Methods, Materials, and Equipment

The two nutrients of interest are nitrogen and phosphorus. Nitrogen is generally eight times more abundant in the natural environment than phosphorus, as most reactive phosphorus is bound to soil components and is not readily available in the water systems (3). Since the excessive plant growth is limited by phosphorus concentrations, this report will focus primarily on this macronutrient.

Three different water samples were collected at all sites, and sent to the Canadian Nuclear Laboratories and the Ministry of Environment for analysis. Each bottle was rinsed three times with water

Table 1: Location of each point in Fig. 1

Point Number	Location
Point 1	SNR-08
Point 2	HC-01
Point 3	NT-01
Point 4	MKR-01
Point 5	MKR-02
Point 6	MKR-03
Point 7	SNR-01
Point 8	SNR-02
Point 9	MC-01
Point 10	BLC-01

from the site in order to remove >99% of contaminants (6). The location with the BioCord (MC-01) was chosen for further study at Algonquin College with TNT Analysis Kits. They were purchased from HACH Industries, and were chosen because of their accuracy in measuring phosphorus concentrations. The TNT Kit 843 was modified slightly to scan for an ultra-low range of phosphorus rather than a low range — instead of adding 2 mL of the water sample, 3.5 mL were added. Solutions from the kit were digested in the HACH DRB200 Digital Reactor Block, and then analyzed in the HACH DR2800 Spectrophotometer.

Figure 2: The BioCord Reactor at MC-01 on July 27th, 2015.

Cattails and arrowheads are planted throughout the top of the raft on Grotop, and polymer strands with biofilm are hanging underneath. Although not visible, iron chains are fastened to the reactor in order to prevent it from floating downstream.

Figure 3: Analysis of the Background Site (BLC-01) in comparison to Ontario guidelines.

BLC-01 clearly conforms to Ontario guideline standards.

Figure 4: Comparison of Snake River at Highway 41 (SNR-01) and Snake River at MacGaghran (SNR-02).

Both phosphorus concentrations are relatively similar, and are not significantly different. Most values yield to the Ontario guidelines.

Figure 5: Comparison of Muskrat River at the Muskrat River Inlet (MKR-01), the Cobden Sewage Plant (MKR-02), and the Muskrat River Outlet (MKR-03).

The sewage plant appeared to have no statistically significant contribution to phosphorus concentrations.

This project tests the BioCord Reactor as a possible solution to eutrophication. The reactor seen in Figure 2 is designed specifically to interact with bacteria to form biofilm. The bacteria consume the excess nutrients to reproduce. The bacteria are electrostatically attracted to the BioCord because the fibers are made up of positively charged poly-vinyl chloride (PVC) strands (2). Plants on top of the simulated rocksoil, called Grotop, interact symbiotically with the bacteria in order to absorb more nutrients (7). The BioCord Reactor and Grotop were purchased from Bishop Water Technologies and GroDan respectively. If proven effective, this reactor can be used in other water systems as a fast, cheap, and environmentally safe solution to eutrophication.

Results and Discussion

Analysis of BLC-01. The background site is situated away from any agricultural or urban activity, and is the primary source of water entering the Muskrat Lake Watershed. It will act as the control for the concentration of natural phosphorus. Figure 3 shows that BLC-01 consistently stays below Ontario standards, suggesting that the source of eutrophication is from within the watershed.

Comparison of SNR-01 and SNR-02. The primary purpose for the comparison of Snake River from SNR-01 to SNR-02 is to evaluate the effect of the natural mixed wood forest, which is the predominant biome of the surrounding area. Figure 4 shows that with no human interference, the environment has little impact on phosphorus concentrations, as they stay relatively low and mostly conform to Ontario guidelines.

Comparison of MKR-01, MKR-02, and MKR-03. These three sites were chosen to determine if the Cobden sewage plant is contaminating the waterways. Figure 5 shows that all three sites have similar phosphorus concentrations throughout the year, which is most likely because all treated water must travel through the Cobden Wetland. A majority of wetlands have a lot of biodiversity, and have very diverse florae; these plants effectively keep phosphorus concentrations low.

Comparison of HC-01, SNR-08, and NT-01. NT-01, the mouth of North Tributary, is the furthest upstream compared to the other two sites. HC-01 — the Upper Harris Drain — is often the receptor of farmland runoff from fertilizer and pesticides because it was anthropogenically constructed to drain farmland during floods. The drain

Figure 6: Comparison of Upper Harris Drain at Cobden Road (HC-01), Snake River below Upper Harris Drain (SNR-08), and the Mouth of North Tributary (NT-01).

Phosphorus concentrations from June to October exceed Ontario guidelines for SNR-08, NT-01, and HC-01.

Figure 7: Phosphorus concentrations upstream and downstream of the BioCord Reactor.

All phosphorus concentrations exceeded the Ontario guidelines. July 3rd, 14th, and 28th showed a decrease in phosphorus concentrations while July 21st and 8th showed an increase.

Figure 8: Tank simulation of the BioCord Reactor.

The phosphorus concentration dropped significantly at the second testing, but remained consistent for the remaining duration of the experiment

enters Snake River at SNR-08; if the drain is making a significant difference on the nutrient concentrations, SNR-08 values should be notably higher than values at NT-01. Figure 6 shows that HC-01 values are, as expected, higher than all the other values, but SNR-08 and NT-01 values are not significantly different. The only exception is in July, where the concentration of NT-01 suddenly spiked. From qualitative notes, the water was unusually stagnant when that sample was taken, which may explain the high concentration. Figure 6 suggests that despite the disproportionate nutrients the farmland is placing into the watershed, agriculture does not have a significant impact on the overall phosphorus concentrations in Snake River.

Evaluation of the BioCord Reactor. The BioCord technology was deployed at MC-01, Pine Valley at Mink Creek. This site was chosen in spring due to high flow, high water level, and accessibility. Although not evident in Figure 2, the water level and water speed decreased so dramatically in July and August that the BioCord PVC cords rested at the bottom of the stream.

The low water level and slow flow observed in the creek may have concentrated the phosphorus and contributed to the significantly high values obtained in Figure 7. The graph demonstrates that the BioCord does not work as well as the theory predicts. There were not enough samples collected, and the data is not consistent enough to make a veritable claim. In order to prevent a similar situation from occurring in the future, a complete analysis of a potential BioCord site from spring to fall, must be conducted.

In addition to the experiment in the field, a replica was conducted in the lab to observe how the BioCord reacts within a closed environment. The BioCord, covered in periphyton gathered from MC-01, was placed inside the tank, along with an aerator in order to simulate water flow. Figure 8 shows that the tank is capable of remediating the high phosphorus levels very well in the first few days, but stagnated for the remainder of the test. It is possible that all the organisms died within the first week of our experiment; unlike a flowing river, there is not a continual source of new bacteria.

Conclusion

The results of this investigation suggests that farmland does not play a major role on phosphorus concentrations. The man-made drain at HC-01, which contains significant agricultural run-off, does not have a significant impact on Snake River. The natural environment of the mixed wood forest, and the wastewater treatment plant, are also not the primary sources of the nutrient overload. The scope of this investigation is small, and more sites need to be analyzed for a longer period of time before any conclusions can be drawn. The

most probable source of error in this investigation is water sampling. It is unfeasible to examine a large section of the watershed, so only a snapshot water sample can be obtained; this represents only a small area of the watercourse. Collectors must confirm that the river is flowing in order to get a more representative section.

The BioCord Reactor did not perform as well as the theory predicts in the lab or in the field. The technology needs to be implemented at more locations in the Muskrat Lake watershed to obtain a larger sample size, and each site must have high water flow and water depth throughout the year. More studies need to be conducted to conclusively say whether or not this technology is a practical solution to eutrophication.

References

1. Hall and Sylvestre. Visualizing and Quantifying Sources of Nutrients in the Agriculturally Dependent Muskrat Lake Watershed. Presentation presented at; Muskrat Lake Symposium; 2014; the Township of Whitewater Region.
2. Yuan X, Qian X, Zhang R, Ye R, Hu W. Performance and microbial community analysis of a novel bio-cord carrier during treatment of a polluted river. *Bioresource Technol.* 2012;117:33-39.
3. Wetzel R. *Limnology*. Burlington: Elsevier Science; c2001.
4. Bishop Water Technologies. Culligan Water Technologies Inc, USA. *Filtration Industry Analyst*. 1998;1998(15):9.
5. Lundqvist L. Games Real Farmers Play: Knowledge, memory and the fate of collective action to prevent eutrophication of water catchments. *Local Environment*. 2001;6(4):407-419.
6. Bruland K, Franks R, Knauer G, Martin J. Sampling and analytical methods for the determination of copper, cadmium, zinc, and nickel at the nanogram per liter level in sea water. *Analytica Chimica Acta*. 1979;105:233-245.
7. Hashida S, Johkan M, Kitazaki K, Shoji K, Goto F, Yoshihara T. Management of nitrogen fertilizer application, rather than functional gene abundance, governs nitrous oxide fluxes in hydroponics with rockwool. *Plant Soil*. 2013;374(1-2):715-725.

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REVIEW

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Implementing Solutions for Muskrat Lake, is relevant, timely and well-written article. I enjoyed reading about a lesser known lake in Ontario. The methodology is strong. The graphs and diagrams makes this article easy to read. Smaller lakes in Ontario are facing Eutrophication at an alarming rate. Therefore, findings of this research is relevant in articulating the need for more such studies. However, the article can benefit from good editing and using APA style referencing. The article also needs to focus a bit more on the concept of nutrient loading. The second page jumps directly to talk about Lake Eutrophication without providing a bit more detail about the interconnection between nutrient loading and eutrophication. Although the author has tried to explain the relevance of his research, it needs more information especially within the context of point and non-point sources of pollution. A separate paragraph about the study area is recommended so that the first paragraph can briefly explain some concepts and the relevance of this study. Methodology and objective of this report needs some clarifications. For example, the author states that "this report hypothesizes that agriculture is the major source of eutrophication due to nutrient overloading from fertilizer runoff, and that water samples downstream of farmland will have higher nitrogen and phosphorus levels than upstream." Then he goes on to say that "Therefore, this report focuses primarily on phosphorus levels because the excessive plant growth is limited by phosphorus concentrations". Leading to confusion whether nitrogen level is being tested or not. Under sub topic 2, Experimental Methods, Materials, and Equipment, the author states that "this project tests the BioCord Reactor as a possible solution to eutrophication" if this is the case, it should be spelled out under the objectives of the paper rather than adding it as an afterthought. This research has a lot of potential and should be continued by improving sampling techniques and collecting long range data. Acknowledgement of sampling errors and not enough data to support its hypothesis, can also be explained due to the non-point nature of other parameters like stormwater discharge. Commendable effort by a high school student!